The invention relates to a power roller for a toroïdal type IVT.

From EP 0462637A a continuous variable transmission is shown wherein a belt extends between two pulley's of varying effective diameter. At least one contact surface of a pully with the belt is covered with a layer realised through Powder Metallurgy. Starting from a base pulley, such layer is arranged during a later stage of manufacturing. Operational conditions of continous variable transmission show relatively low contact pressure between the belt and the pully. Operation is generally dry i.e. without the presence of a lubricant.

JP 05239602 discloses the production of high bearing pressure parts starting from an alloy powder having a composition of by weight, $\leq$2% C, 2 to 5% Cr, $\leq$2% Si, $\leq$2% Mn, $\leq$2% V, $\leq$12% Mo and $\leq$24% W and satisfying 6 $\leq$Weq $\leq$24.

JP 05132743 discloses a bearing reamarkably improved in fatigue life and comprises by weight, $\leq$ 2.0% C,2.0-5.0% Cr, $\leq$ 2.0% Si, $\leq$2.0% Mn, $\leq$2.0% V, h12.0% Mo, $\leq$24.0% W, and the balance Fe with inevitable impurities and where 6$\leq$Weq$\leq$24 is statisfied when W÷2 Mo = Weq and also ^C specified by ^C=C-(0.06Cr + 0.033W + 0.063Mo + 0.2V) satisfies ^C$\leq$0.

The invention relates to a powerroller of an IVT component. Below an IVT has to be understood as IVT of the toroïdal type and more particular the disk or rollers thereof. The contact surfaces of the disks, rollers respectively are subjected to high contact loadings under conditions wherein a lubricant is present. With regard to roller bearings, the contact pressure is considerably higher between the circumferential surface of the powder roller and raceway of the disk. High contact fatigue strength requirements are set as well as a requirement for static load capacity, without a lubrication film being present.

It has been found that an ordinary rolling bearing steel does not meet these requirements.

The invention aims to provide a power roller which has improved properties

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making a particularly suitable for IVT, S.

According to the invention this is realised in that said power roller is integrally shaped through powder metallurgy techniques from a steel comprising

0.75 - 1.85 wt % C
0.10 - 0.45 wt% Si
0.15 - 0,.50 wt% Mn
3.50 - 4.50 wt% Cr
4.00 - 11.00 wt% Mo
0.90 - 5.25 wt% V
0.10-13.00 wt% W
balance Fe and impurities.

Integrally shaped is to be understood as fully comprising PM material. This in contrast to EP-0462637 wherein only a layer of PM material is provided. Only through integral manufacturing of a IVT component such as a disk and more preferably a power roller sufficient service life can be realised at the high contact fatigue loads revealing.

As indicated above the invention is used for the manufacturing of power rollers of an IVT.

According to a preferred embodiment a PM M62 type steel is used comprising:

1.25 - 1.35 wt % C
0.15 - 0.4 wt % Si
0.15 - 0.40 wt % Mn
3.50 - 4.25 wt % Cr
10.00 - 11.00 wt % Mo
1.80 - 2.20 wt % V
5.75 - 6.75 wt % W.

Although the costs for these kinds of steels are substantially higher than the costs for ordinary rolling bearing steel, such as ASTM A295 52100, the properties thereof make it much more suitable for the CVT/IVT disk and power roller components than ordinary rolling bearing steels. Through a suitable treatment a very high hardness of the surface of a PM M62 steel article can be realised. However, in contrast to ordinary steels produced to very high hardnesses the toughness of the core material in PM M62 does not deteriorate. This means that the toughness/hardness ratio is significantly higher than conventionally martensitic hardened ASTM A295 52100 rolling bearing steel.

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The invention also relates to a troïdal type IVT comprising powerrollers according to one of the preceding claims and a disk being integrally shaped through powder metallurgy techniques. Such a disk can be produced as described above for the powerroller.

The power metallurgy steel can be produced with any method known in the art. As example the following steps are given:

Vacuum induction melting and refining of the power metallurgy steel composition,

Nitrogen gas powder atomisation,

Powder grading and canning,

Hot isostatic pressing and

Hot forging.

Other techniques for economical plastic shaping are also included.

Preferably, powder metallurgy high alloy steels are subjected to a secondary hardening treatment. Preferably, this is realised through austenising at 1205 ± 5°C for 5-10 minutes followed by gas, oil or salt quenching and -tempering at about 550 °C. In the preferred embodiment given above wherein an M62 steel is used, the hardness can be as high as 67 HRC with high temperature hardness properties.

The invention will be further elucidated referring to the enclosed figures.

Fig. 1 shows an example of an IVT;

Fig. 2 shows a comparative graph for the contact stress; and

Fig. 3 shows a comparative graph for blunt notch toughness.

In fig. 1 an example of an CVT/IVT is given. In the most general embodiment the CVT/IVT comprises input disks 1 connected to the output shaft of an engine and an opposed output disk 2 connected to a drive chain or further gear box components of a vehicle or any other item which has to be driven with a variable ratio. In between are a number of power rollers 3. Power rollers 3 can be journalled on any shaft and the axis thereof is indicated by 4. This shaft can make a rotational movement in the sense of arrow 5. Through rotation of other rollers in the sense of arrow 5 the transmission ratio between the input and output disk will change. As shown in fig. 1 power roller 3 engages the input disk near its centre line whilst the output disk is engaged remote from this centre line. There is a pressure force clamping the circumferential surface of the power rollers to the raceway 8 of the input disk and the raceway 9 of the output disk respectively. This clamping force is schematically referred to by arrows 10. The CVT/IVT shown in fig. 1 is also known as 'Torotrak IVT'. Other means are also used in the art but for all embodiments it is essential that at least three power rollers are provided which make some tilting movement according to arrow 5 in order to change the ratio of transmission between an input and an output disk. It has been shown that such structure can give a 15% increased efficiency as compared to conventional automatic transmissions. In contrast to rolling bearing there is no lubrication film between the adjacent components of the structure.

The circumferential surface of each power roller as well as the raceways 8 and 9 are subjected to considerable loadings. Probably this is one of the reasons that up to now this technique was not generally accepted. For example, the maximum contact

stress between the circumferential surface of the power rollers and the related raceway could be as high as 4 GPa. This is far higher than the contact pressure encountered in usual rolling bearings. Furthermore, the tilting movement according to arrow 5 introduces slip of the rollers relative to the disks. Such a slip is not present in rolling bearings. Fatigue cracking and fracture due to repetitive bending stresses have been reported. The area of the disk within circle 11 is particular vulnerable. This means that the combined rolling contact fatigue strength of the traction surfaces (raceways) and fatigue fracture strength should be improved. Below a very schematic overview of the loading of the several components of the CVT/IVT transmission is given.

IVT-Components	~ Characteristics	Failure Mode
Input Disk- Spine Connection	Torsional load at spline radii	Structural fatigue cracking
Input disk against power roller via traction fluid to stop slippage	Up to ~3.5 GPa contact pressure	•Rolling contact fatigue spalling •Surface distress •Structural load accelerated contact fatigue
Power rollers	Up to ~3.5 GPa contact pressure	•Rolling contact fatigue spalling •Surface distress
Significant clamping forces across disk & power rollers via hydraulic piston	Bending structural stress	Structural fatigue cracking
Drive disk via chain sprocket	Bending forces at output drive	Bending fatigue cracks
Disk & power rollers	High temperatures (up to ~ 120.°C) and structural stresses	Growth & axial clearance increase
Disk & power rollers	Vibratory loads	Accelerated structural fatigue cracking

Fig. 2 shows the rolling contact fatique life at different contact stresses. The usual rolling bearing steel ASTM A295 52100 (dotted line) is compared with the steel according to the invention PM M62 (continuous line). The number of cycle's (L50) is in million stress cycles.

In fig. 3 the hardness against blunt notch toughness is shown. -.. is a 52100 steel whilst - ■ - shows PM M62. From this figure it is clear that in spite of the very high hardness of the PM M62 steel (67 HRC) , the toughness is no less than standard martensitic 52100 rolling bearing steel.

Through the use of a powder metallurgy steel and more particular M62 composition it is possible to decrease the size of both disks and power rollers of a CVT/IVT at the same torque output.

Although the invention has been described above referring to M62 steel as preferred embodiment, it has to be understood that other high alloy powder metallurgy steels can be used in CVT/IVT and are within the range of the invention.